

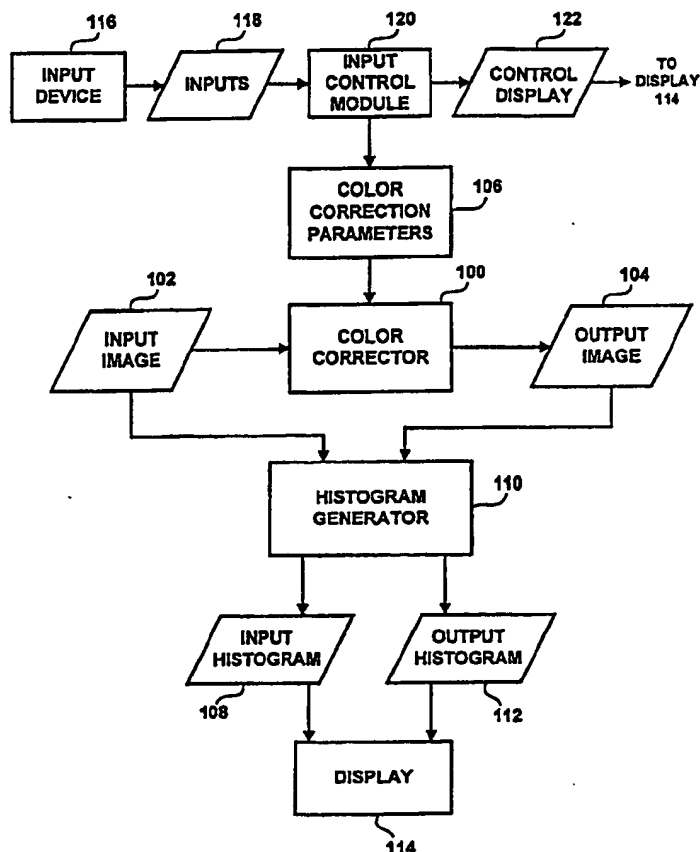
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(54) Title: APPARATUS AND METHOD FOR GENERATING AND DISPLAYING HISTOGRAMS OF COLOR IMAGES FOR COLOR CORRECTION

(57) Abstract

Histograms may be generated for composite video signals in addition to various component video data. Both input and output histograms may be displayed simultaneously, and may be dynamically updated while a user adjusts control points which correspond to color correction parameters for color correction. A representation of a color distribution of an image defined by a composite video signal may be generated by identifying high and low values of for each pixel in the image in a composite video color space. A representation of the distribution of the high and low values corresponding to the pixels in the image is generated. The representation of a color distribution may be a histogram. The image may be defined by component video data, such that the component video data for each pixel in the image is converted into high and low values in a composite video color space. The image may be displayed in association with the representation of the color distribution. Color correction may be performed on the image to obtain an output image, for which a representation of a color distribution of the output image also may be determined. The representation of the color distribution of the image may be displayed in association with the representation of the color distribution of the output image.



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APPARATUS AND METHOD FOR GENERATING AND DISPLAYING HISTOGRAMS OF COLOR IMAGES FOR COLOR CORRECTION

BACKGROUND

5 Color correction devices for color images generally provide a mechanism through which color characteristics may be adjusted. The image to be corrected and sometimes a histogram or other representation of the distribution of color in the image typically are displayed to a user. Histograms generally are provided for each component of component video data. Color correction devices typically show the input image prior to correction and
10 its color distribution histogram. After adjustments are made to the color, an output image is generated. A histogram also may be generated for and displayed with the displayed output image.

SUMMARY

15 Histograms may be generated for composite video signals in addition to various component video data. Both input and output histograms may be displayed simultaneously, and may be dynamically updated while a user adjusts control points which correspond to color correction parameters for color correction.

 Accordingly, in one aspect, a representation of a color distribution of an image
20 defined by a composite video signal may be generated by identifying high and low values of for each pixel in the image in a composite video color space. A representation of the distribution of the high and low values corresponding to the pixels in the image is generated. The representation of a color distribution may be a histogram. The image may be defined by component video data, such that the component video data for each pixel in the image is
25 converted into high and low values in a composite video color space. The image may be displayed in association with the representation of the color distribution. Color correction may be performed on the image to obtain an output image, for which a representation of a color distribution of the output image also may be determined. The representation of the color distribution of the image may be displayed in association with the representation of the
30 color distribution of the output image.

 In another aspect, a graphical user interface for a color corrector which changes color in an input image to provide an output image, includes an input device manipulable by a user to generate signals. An input control module has an input for receiving signals from the input

device and an output providing a control display in accordance with the signals received from the input device. A histogram generator has an input for receiving the input image and the output image and an output providing a representation of the distribution of color in the input image and the output image. A display receives and displays to a user the control display and the representation of the distribution of color in the input and output images. The graphical user interface may be responsive to signals to the input control module, for modifying a relationship between the input and output images and for modifying the representation of the distribution of color in the output image.

In another aspect, a system for color correction of composite output signals using component video may receive control points defining a curve describing an input to output relationship in the composite video signal. A gain value and an offset value may be determined from the control points. A composite adjustment matrix may be generated from the gain and offset values to provide as color correction parameters to the color corrector.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings,

Fig. 1 is a data flow diagram illustrating how histograms and a control display may be generated for a color corrector;

Figs. 2A and 2B illustrate an example user interface having input and output histograms and a control display;

Fig. 3 is a flow chart illustrating how an input histogram for an input image having component video data may be generated;

Fig. 4 is a flow chart illustrating how an output histogram for an output image may be generated;

Fig. 5 is a diagram illustrating a probability distribution function of a sine wave;

Fig. 6 is a flow chart describing how a composite histogram may be generated;

Fig. 7 is a flow chart describing how a composite adjustment matrix may be generated for color correction;

Fig. 8 is a flow chart describing in more detail how a composite adjustment matrix may be generated;

Fig. 9 is a data flow diagram illustrating how an approximate output histogram may be generated from an input histogram using color correction controls; and

Fig. 10 is a flow chart describing how an approximate output histogram may be generated from an input histogram using color correction controls.

DETAILED DESCRIPTION

5 The following detailed description should be read in conjunction with the attached drawing in which similar reference numbers indicate similar structures. All references cited herein are hereby expressly incorporated by reference.

Referring now to Fig. 1, a color corrector 100 receives an input image 102 to produce an output image 104 according to color correction parameters 106. A histogram generator
10 110 generates an input histogram 108 from the input image 102. Histogram generation is described, for example, in Digital Image Processing, Second Edition., by Rafael Gonzales, Addison-Wesley, 1987, pages 144-146 and page 149. The same or another histogram generator 110 also produces an output histogram 112 from the output image 104. The input and output histograms may be output to a display 114. A user also may manipulate an input
15 device 116 to provide inputs 118 according to which an input control module 120 adjusts the color correction parameters 106. The input control module 120 generates a control display 122, which also may be displayed on the display 114. The displayed input and output histograms and the control display, in response to signals from the input device, provide a graphical user interface for color correction.

20 An example graphical user interface will now be described in connection with Fig. 2A. Both the input histogram 108 and output histogram 112 are organized in a window on the display 114 with the control display 122. This example display may be used to illustrate histograms for component video data such as red, green, blue and master color video data. Component video data in other color spaces such as YCrCb and HSL also may be represented
25 using this interface. In Fig. 2A, an input region 200 illustrates the input histogram. An output region 202 illustrates the output histogram. A control region 204 provides a mechanism through which the color correction parameters 106 (Fig. 1) may be set. In this example, the control region 204 displays three control points 206, 208 and 210 that are controlled by a user to set a white point, grey point and black point, respectively. For
30 example, the position of these control points on the display may be controlled using conventional techniques using a cursor control device, such as a mouse, trackball, touch pad or touch screen. Numerical values associated with these control points may be displayed,

such as shown at 212 and 214. These values also may be shown graphically and in association with the histogram regions 200 and 202 such as shown at 216 and 218. These control points are translated using conventional techniques into color correction parameters 106 for red, green and blue video levels to be used by the color corrector 100.

5 Referring now to Fig. 2B, an example organization in a window of input and output histograms and a control display for a composite video signal is shown. In particular, an input region 250 illustrates an input histogram of the composite signal corresponding to the input image. An output region 252 illustrates an output histogram of the composite signal corresponding to the output image. A control region 254 provides a mechanism through
10 which composite video levels may be set, which are translated into color correction parameters (106 in Fig. 1). In this example, the control region 254 displays two control points 256 and 258 that are controlled by a user to set minimum and maximum composite video levels, respectively. The position of these control points on the display may be controlled in the same manner as the control points in Fig. 2A. Numerical values associated
15 with these control points may be displayed, such as shown at 260 and 262. These values also may be shown graphically and in association with the histogram regions 250 and 252, such as shown at 264 and 266. These control points are translated using conventional techniques into color correction parameters 106 for composite video levels to be used by the color corrector 100.

20 Fig. 3 is a flow chart describing in one embodiment how an input histogram for an input image defined by component video data may be generated. In step 300, the histogram data are initialized. For example, for each of the possible values of each of the possible components of a pixel in an input image, a count of the pixels having that value for the component is set to zero. The counts for each possible component value may be stored in an
25 array indexed by the component value. Next, in step 302, the number of pixels having each possible component value is counted. For example, for each pixel in the image, its representation may be converted to component values in the R, G, B color space. For example, a set of values in the Y, Cr, Cb color space for a pixel are converted into a set of values in the R, G, B color space. The value of each component for the pixel is used to index
30 the count for that component in an array representing the histogram data. The count for that component value is incremented. The maximum count for each component then is identified from the histogram data in step 304. For example, the component value for each component

for which the count is the maximum is identified. A normalization factor for displaying the input histogram is then determined for each component in step 306. For example, a factor such as $1/(\text{maximum} * y)$, where y is a value close to one, such as 1.1, may be used. The count for each component value is multiplied by the normalization factor to normalize the input histogram for display in step 308.

Referring now to Fig. 4, a flow chart describing in one embodiment how an output histograms for an output image defined by component video data may be generated, will now be described. Similar to generation of the input image, in step 410, the histogram data are initialized. Next, in step 412, the number of pixels having each possible component value is counted. A normalization factor for displaying the histogram is then determined in step 414, using the maximum value for input histogram. In particular, the maximum count identified for each component in the input histogram in step 304 in Fig. 3 is used to compute the normalization factor for the output display. Using such a normalization factor, the scale factors for the input and output histogram displays are about the same. The normalization factor may be, for example, $1/\text{maximum}$. The denominator of the normalization factor for the input display may be scaled slightly differently, for example by a factor such as 1.1, as described above. This small difference in normalization factors for the input and output histograms permits the occurrence of significance spikes in the output histogram to be shown, at least in part, in the output histogram. The count for each component value is multiplied by the output normalization to normalize the output histogram for display Step 416.

Generating a histogram for a composite video signal is different from generating a histogram of component video data. In particular, a composite video is an analog signal that uses a high frequency subcarrier to encode color information. The subcarrier is a sine wave of which the amplitude is modulated by the saturation and hue is encoded as a phase difference from a color burst. Such a signal is described in more detail in Video Demystified, Second Edition, by Keith Jack, HighText Publications, 1996, pages 66-67, and SMTPE Standards for NTSC Television, SMPTE, pages EG27.

Fig. 5 illustrates a graph 500 of a probability distribution function of a sine wave. In particular, Fig. 5 illustrates the probability distribution function of the function $y = \sin(x)$, where x is a uniform-random variable that ranges from $-\bar{y}$ to \bar{y} , and where y ranges from -1 to 1. This probability distribution function is represented by the following equation:

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An approximation of a histogram of a sine wave is a count of only the values where there are pronounced spikes in the probability distribution function, shown at 502 and 504, namely the minimum and maximum of the sine wave. These values may be used to approximate a composite histogram using the digital component video data representing each pixel. How composite histograms are generated will now be described in connection with the flow chart of Fig. 6.

Referring now to Fig. 6, the composite histogram is initialized in step 600. For example, the composite histogram may be represented by an array, indexed by a value (e.g., in Institute of Radio Engineers (IRE) units or in millivolts (mVolts)), that stores a count of pixels for each possible value. To initialize the array, maximum and minimum values are computed from the image. The size of the array is initialized to the range of the values in the image. A count stored in the array for each value is initialized to zero.

In step 602, the composite value corresponding to each pixel is determined. This process is described in more detail below in connection with Fig. 7. In general, given a representation of a pixel in a color space, e.g., YUV component space, the corresponding composite value (in units of IRE or mVolt) is computed using known techniques. For the composite value of each pixel in the image, the count for that composite value is incremented in step 604. A normalization factor is determined in step 606. As with the histograms for the component video data, the input and output histograms for the composite signal may have normalization factors determined in different ways. For example, the input composite histogram may have a normalization factor that is determined by identifying the maximum count for all of the composite values and then scaling the maximum count by a factor, such as 1.1. The inverse of this scaled maximum value may be used as the normalization factor on the input histogram. The output histogram may use a normalization factor which is the inverse of the maximum count identified for the input histogram. The count for each composite value in a composite histogram is multiplied by the normalization factor to normalize the histogram for display in step 608.

How a composite value is determined for a pixel will now be described in connection with Fig. 7. For each pixel in the image, its component values are translated into a luminance component value and chrominance (UV) component values in step 700. In particular:

the luminance component value = $(100 - \text{setup}) * (Y - 16) / 219 + \text{setup}$;

the U component value = $(0.436) * (100 - \text{setup}) * (Cb - 128) / 112$; and

the V component value = $(0.615) * (100 - \text{setup}) * (\text{Cr} - 128) / 112$.

Next, the chrominance composite value is computed as the square root of the sum of squares of the U component and V component values in step 702. The composite low and composite high values are then computed in step 704 as, respectively, the difference and sum
5 of the Y composite and C composite values.

Having now described the graphical user interface and the generation of histograms, how the color correction parameters are determined and applied from control points will now be described. Such parameters may be generated using conventional techniques for component video data. For composite video data, the two control points 256 and 258 in the
10 control region 254 in Fig. 2B are low and high points that are used to create a composite adjustment matrix that is used as part of a matrix multiply operation that implements color correction. Such matrix multiplication for color correction is described in more detail in Video Demystified, Second Edition, by Keith Jack, HighText Publications, 1996, pages 421-422. The composite controls include a low input value (compLowIn), a low output value
15 (compLowOut), a high input value (compHighIn) and a high output value (compHighOut). A composite adjustment matrix is defined as follows:

The flow chart of Fig. 8 illustrates how the composite adjustment matrix is calculated. In Fig. 8, the gain is computed in step 800, for example by determining the slope defined by
20 the two control points, using the following equation:

The luma offset in IRE units is computed in step 802, for example by using the equation:

25 The offset for the composite adjustment matrix is computed using the offset in IRE units in the following manner. To convert pixel data between IRE and YCbCr values, the following equation may be used.

In IRE units, to find a new pixel value (Y'_{IRE}) from a current pixel (Y_{IRE}) using the
30 gain and offset in IRE units, the following equation may be used:

The offset therefore is defined by the following equation:

The composite adjustment matrix using the gain and offset values is used to calculate a color correction matrix for color correction Step 804.

It may be desirable to modify the output histogram while the user adjusts the control points so that the user may view the effects of any change to the control points on the output histogram. In the system shown in Fig. 1, after the control points are adjusted by the user, the color correction parameters corresponding to these control points are applied to the color corrector to create the output image, from which an output histogram may be generated. Alternatively, as shown in Fig. 9, the color correction parameters 106 also may be provided to a histogram modifier 900, while the user adjusts the control points, which generates an approximate output histogram 902 based on the output histogram 112. This generation of the approximate output histogram is generated, in the following manner. After the user adjusts the control points, the output histogram may be reconstructed using the actual output image.

Fig. 10, the input histogram data is accessed in step 1000. From the user control input values, a gain an offset and clip values are determined in step 1002. For example, given the user specified parameters compLowIn, compLowOut, compHiIn, and compHiOut, the composite gain and offset may be determined by the following equations:

The composite offset may be computed by the following equation:

20

In step 1004, the output histogram data is generated using the determined gain, offset and clip values and the input histogram data. In particular, for each index in the output histogram, the output histogram is initialized to zero. For each index C in the input histogram, its corresponding index in the output histogram is found by the following equation:

25

*Output Index = compLowOut when C is less than compLowIn;
compHiOut when C is greater than compLowOut; and
compGain * C + compOffset otherwise.*

Given the output index that corresponds to an input index C in the input histogram, the number of output values is incremented by the number of input values for the input index by the following equation:

30

output histogram [output index] = output histogram [output index] + input histogram [input index]

The normalization factor used for the prior input histogram is used as noted in step 1006. The output histogram is displayed in step 1008.

5 It should be understood that the forgoing equations may be readily generalized to any component representation of the video data by computing the gain and offset and clip values from control inputs.

A computer program may include a main unit connected to both an output device which displays information to a user and an input device which receives input from a user.
10 The main unit may include a processor connected to a memory system via an interconnection mechanism. The input device and output device also are connected to the processor and memory system via the interconnection mechanism.

It should be understood that one or more output devices may be connected to the computer system. Example output devices include a cathode ray tube (CRT) display, liquid
15 crystal displays (LCD) and other video output devices, printers, communication devices such as a modem, storage devices such as disk or tape. and audio output. It should also be understood that one or more input devices may be connected to the computer system.

Example input devices include a keyboard, keypad, track ball, mouse, pen and tablet, communication device, and data input devices such as audio and video capture devices. It
20 should be understood that the invention is not limited to the particular input or output devices used in combination with the computer system or to those described herein.

The computer system may be a general purpose computer system which is programmable using a computer programming language, such as C++, JAVA or other language, such as a scripting language or even assembly language. An example computer
25 system is the Infinite Reality computer system from Silicon Graphics, Inc. The computer system may also be specially programmed, special purpose hardware, or an application specific integrated circuit (ASIC). In a general purpose computer system, the processor is typically a commercially available processor, of which the series x86 and Pentium series processors, available from Intel, and similar devices from AMD and Cyrix, the 680X0 series
30 microprocessors available from Motorola, the PowerPC microprocessor from IBM and the Alpha-series processors from Digital Equipment Corporation, and the MIPS microprocessor from MIPS Technologies are examples. Many other processors are available. Such a

microprocessor executes a program called an operating system, of which WindowsNT, Windows 95 or 98, IRIX, UNIX, Linux, DOS, VMS, MacOS and OS8 are examples, which controls the execution of other computer programs and provides scheduling, debugging, input/output control, accounting, compilation, storage assignment, data management and
5 memory management, and communication control and related services. The processor and operating system defines computer platform for which application programs in high-level programming languages are written.

A memory system typically includes a computer readable and writeable nonvolatile recording medium, of which a magnetic disk, a flash memory and tape are examples. The
10 disk may be removable, known as a floppy disk, or permanent, known as a hard drive. A disk has a number of tracks in which signals are stored, typically in binary form, i.e., a form interpreted as a sequence of one and zeros. Such signals may define an application program to be executed by the microprocessor, or information stored on the disk to be processed by the application program. Typically, in operation, the processor causes data to be read from
15 the nonvolatile recording medium into an integrated circuit memory element, which is typically a volatile, random access memory such as a dynamic random access memory (DRAM) or static memory (SRAM). The integrated circuit memory element allows for faster access to the information by the processor than does the disk. The processor generally manipulates the data within the integrated circuit memory and then copies the data to the disk
20 after processing is completed. A variety of mechanisms are known for managing data movement between the disk and the integrated circuit memory element, and the invention is not limited thereto. It should also be understood that the invention is not limited to a particular memory system.

Such a system may be implemented in software or hardware or firmware, or a
25 combination of the three. The various elements of the system, either individually or in combination may be implemented as a computer program product tangibly embodied in a machine-readable storage device for execution by a computer processor. Various steps of the process may be performed by a computer processor executing a program tangibly embodied on a computer-readable medium to perform functions by operating on input and generating
30 output. Computer programming languages suitable for implementing such a system include procedural programming languages, object-oriented programming languages, and combinations of the two.

It should be understood that invention is not limited to a particular computer platform, particular processor, or particular high-level programming language. Additionally, the computer system may be a multiprocessor computer system or may include multiple computers connected over a computer network. It should be understood that each module or
5 step shown in the accompanying figures may correspond to separate modules of a computer program, or may be separate computer programs. Such modules may be operable on separate computers.

Having now described a few embodiments, it should be apparent to those skilled in the art that the foregoing is merely illustrative and not limiting, having been presented by way
10 of example only. Numerous modifications and other embodiments are within the scope of one of ordinary skill in the art and are contemplated as falling within the scope of the invention.

CLAIMS

1. A method for generating a representation of a color distribution of an image defined by a composite video signal, comprising:
 - identifying high and low values of for each pixel in the image in a composite video
 - 5 color space; and
 - generating a representation of the distribution of the high and low values corresponding to the pixels in the image.
2. The method of claim 1, wherein the representation of a color distribution is a
- 10 histogram.
3. The method of claim 1, wherein the image is defined by component video data, and wherein the step of identifying comprises converting the component video data for each pixel in the image into high and low values in a composite video color space.
- 15 4. The method of claim 1, further comprising:
 - displaying the image in association with the representation of the color distribution.
5. The method of claim 1, further comprising:
 - 20 performing color correction on the image to obtain an output image; and
 - generating a representation of a color distribution of the output image defined by a composite video signal.
6. The method of claim 5, further comprising:
 - 25 displaying the representation of the color distribution of the image in association with the representation of the color distribution of the output image.
7. An apparatus for generating a histogram for an image of a composite video signal using video data representing a pixel in the image as component video data, comprising:
 - 30 means for identifying high and low values of for each pixel in the image in a composite video color space; and

means for generating a representation of the distribution of the high and low values corresponding to the pixels in the image.

8. The apparatus of claim 7, wherein the representation of a color distribution is a
5 histogram.

9. The apparatus of claim 7, wherein the image is defined by component video data, and wherein the means for identifying comprises means converting the component video data for each pixel in the image into high and low values in a composite video color space.

10

10. The apparatus of claim 7, further comprising:
means for displaying the image in association with the representation of the color distribution.

15 11. The apparatus of claim 1, further comprising:
means for performing color correction on the image to obtain an output image; and
means for generating a representation of a color distribution of the output image defined by a composite video signal.

20 12. The apparatus of claim 11, further comprising:
means for displaying the representation of the color distribution of the image in association with the representation of the color distribution of the output image.

13. An apparatus for generating a histogram for an image of a composite video signal
25 using video data representing a pixel in the image as component video data, comprising:
a color space converter having an input for receiving component video data for each pixel in the image and an output providing high and low values in a composite video color space for each pixel; and
a histogram generator having an input for receiving the high and low values in the
30 composite video color space for the pixels in the image and an output for providing a representation of the distribution of the high and low values in the image:

14. A computer program product for generating a representation of a color distribution of an image defined by a composite video signal, comprising:

a computer readable medium having computer program instructions stored thereon, wherein the computer program instructions, when executed by a processor, perform the steps of:

identifying high and low values of for each pixel in the image in a composite video color space; and

generating a representation of the distribution of the high and low values corresponding to the pixels in the image.

15. A graphical user interface for a color corrector which changes color in an input image to provide an output image, comprising:

an input device manipulable by a user to generate signals;

an input control module having an input for receiving signals from the input device and an output providing a control display in accordance with the signals received from the input device;

a histogram generator having an input for receiving the input image and the output image and an output providing a representation of the distribution of color in the input image and the output image;

a display for receiving and displaying to a user the control display and the representation of the distribution of color in the input and output images.

16. The graphical user interface of claim 15, further comprising, means, responsive to signals to the input control module, for modifying a relationship between the input and output images and for modifying the representation of the distribution of color in the output image.

17. A computer program product for a graphical user interface for a color corrector which changes color in an input image to provide an output image, comprising:

a computer readable medium having computer program instructions stored thereon, wherein the computer program instructions, when executed by a processor, perform the steps of:

receiving signals from an input device;

generating a control display in accordance with the signals received from the input device;

generating a representation of the distribution of color in the input image and the output image; and

5 displaying to a user the control display and the representation of the distribution of color in the input and output images.

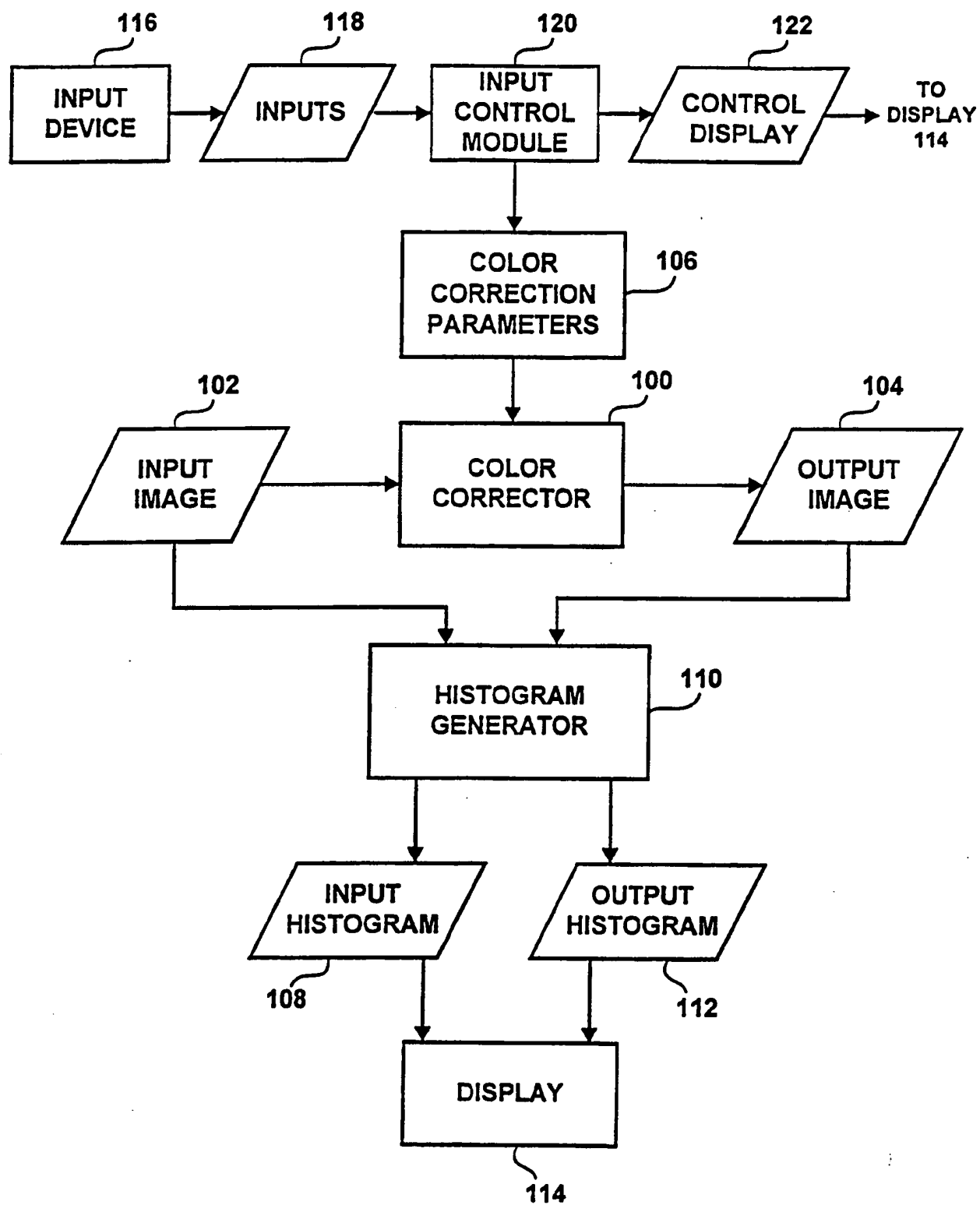
18. A system for color correction of composite output signals using component video, comprising:

10 receiving control points defining a curve describing an input to output relationship in the composite video signal;

determining a gain value from the control points;

determining an offset value from the control points;

generating a composite adjustment matrix from the gain and offset values to provide
15 as color correction parameters to the color corrector.

**FIG. 1**

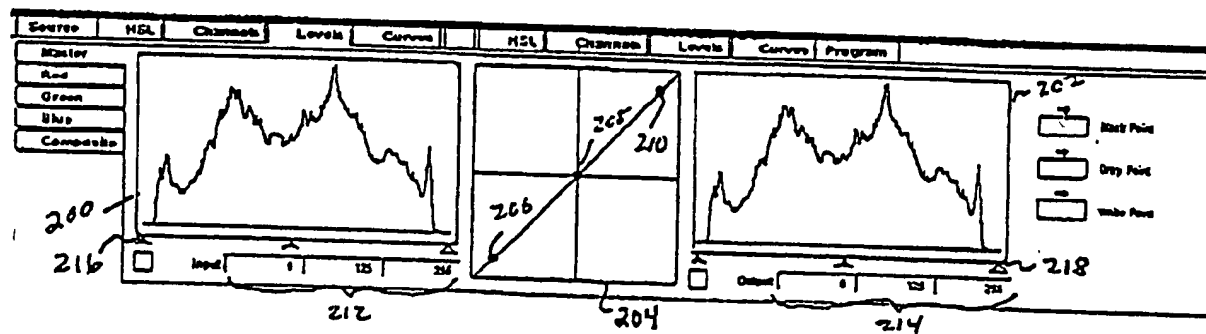


FIG. 2A

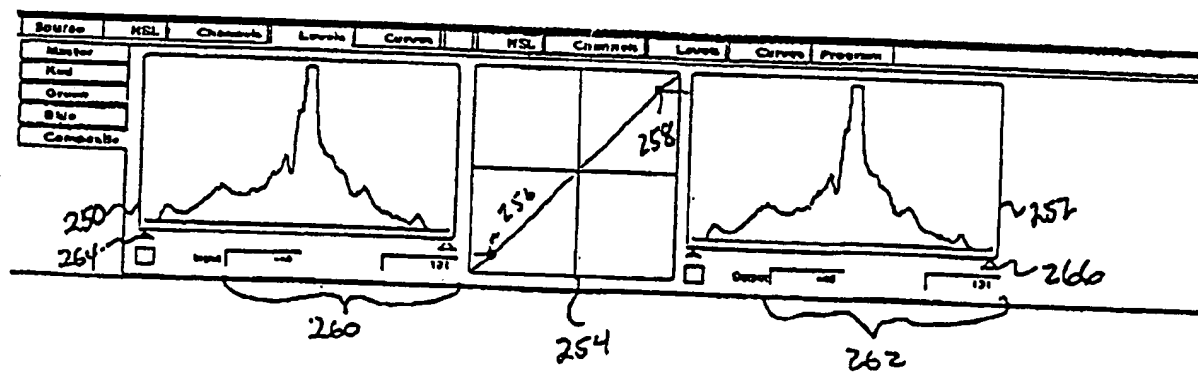
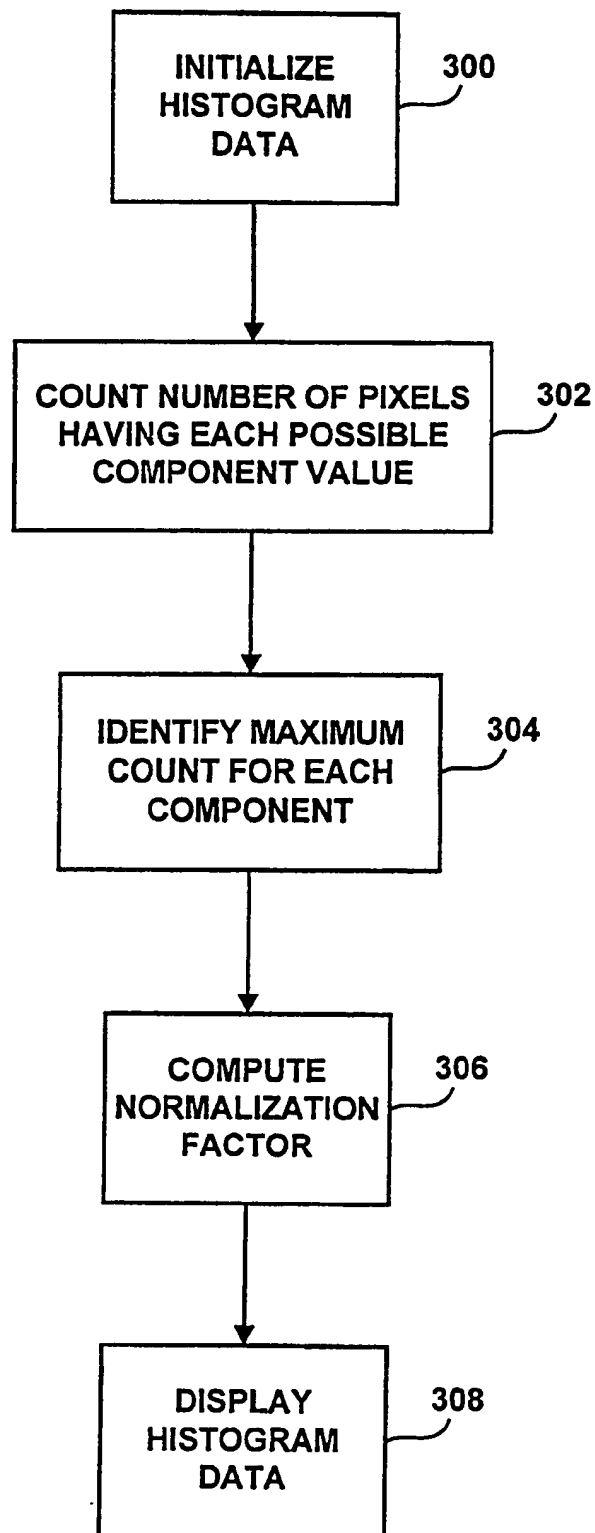
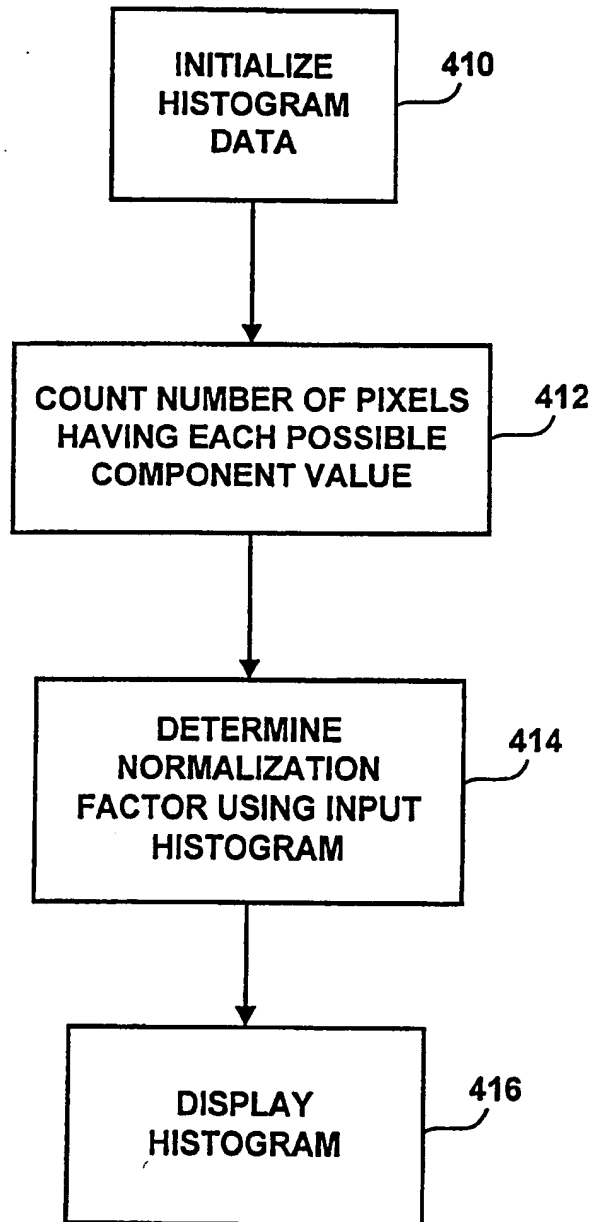


FIG. 2B

**FIG. 3**

**FIG. 4**

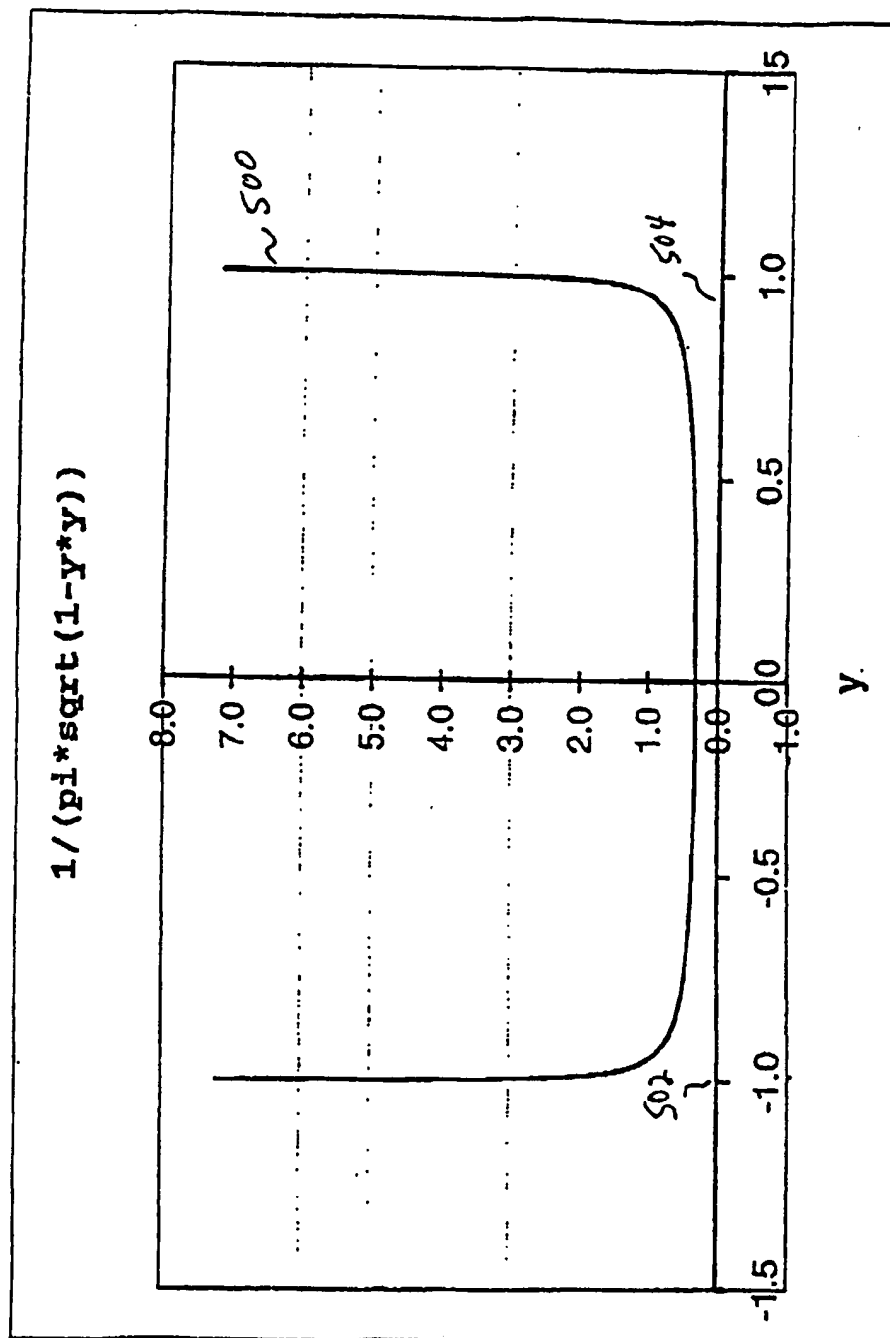
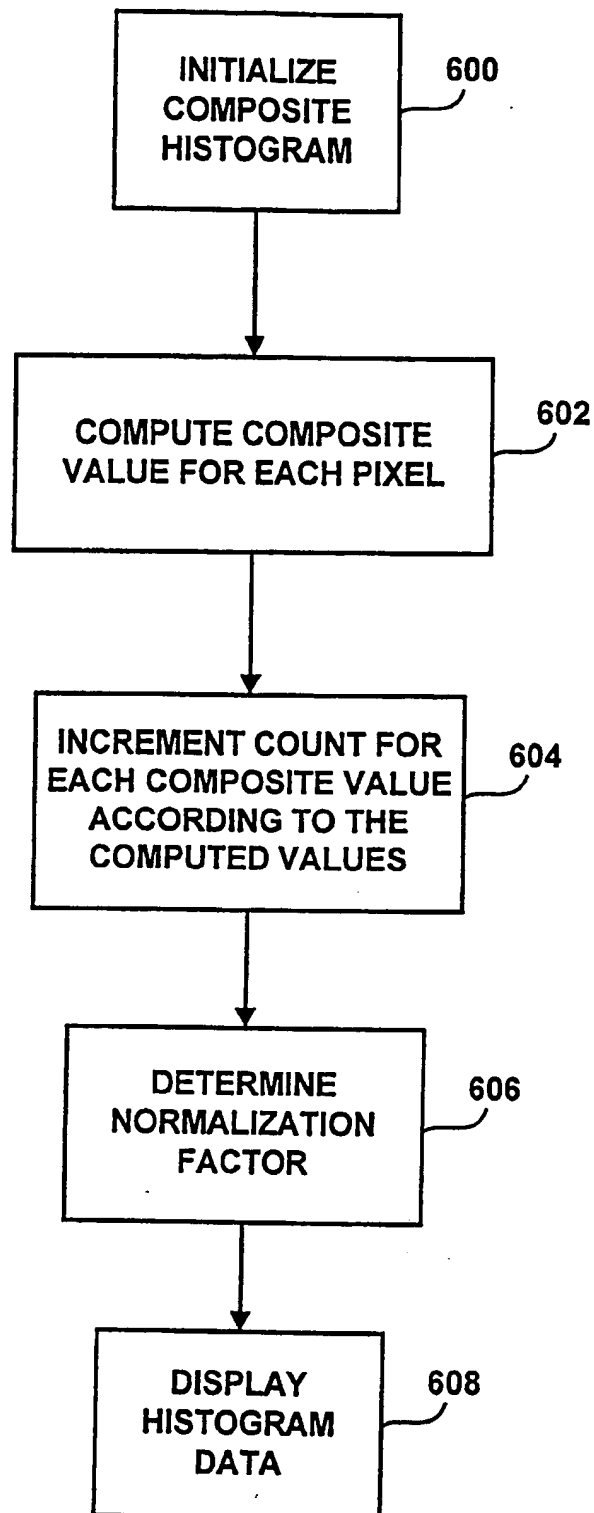
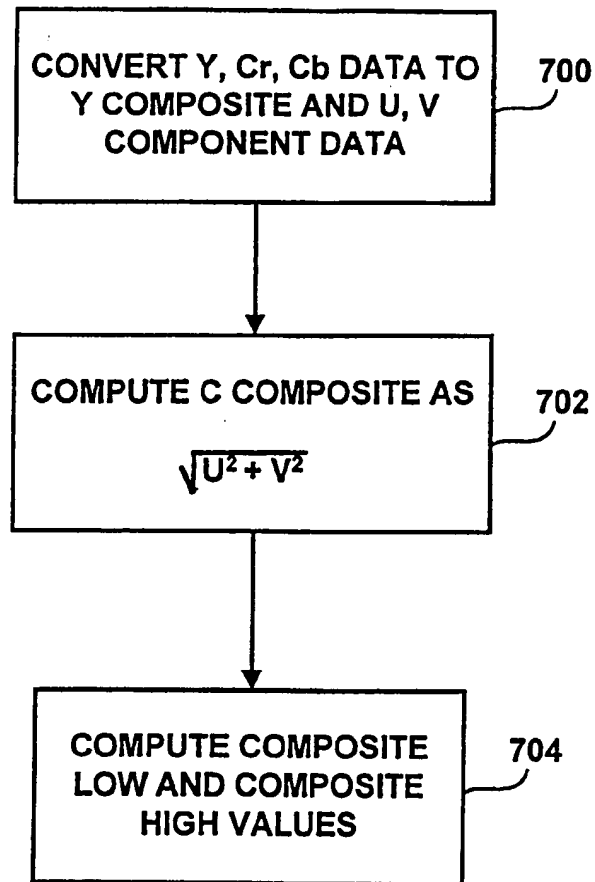
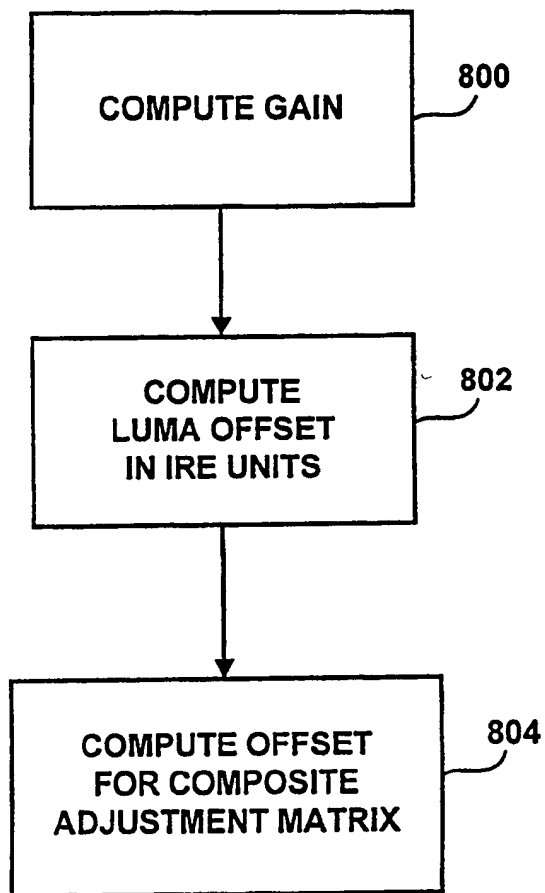
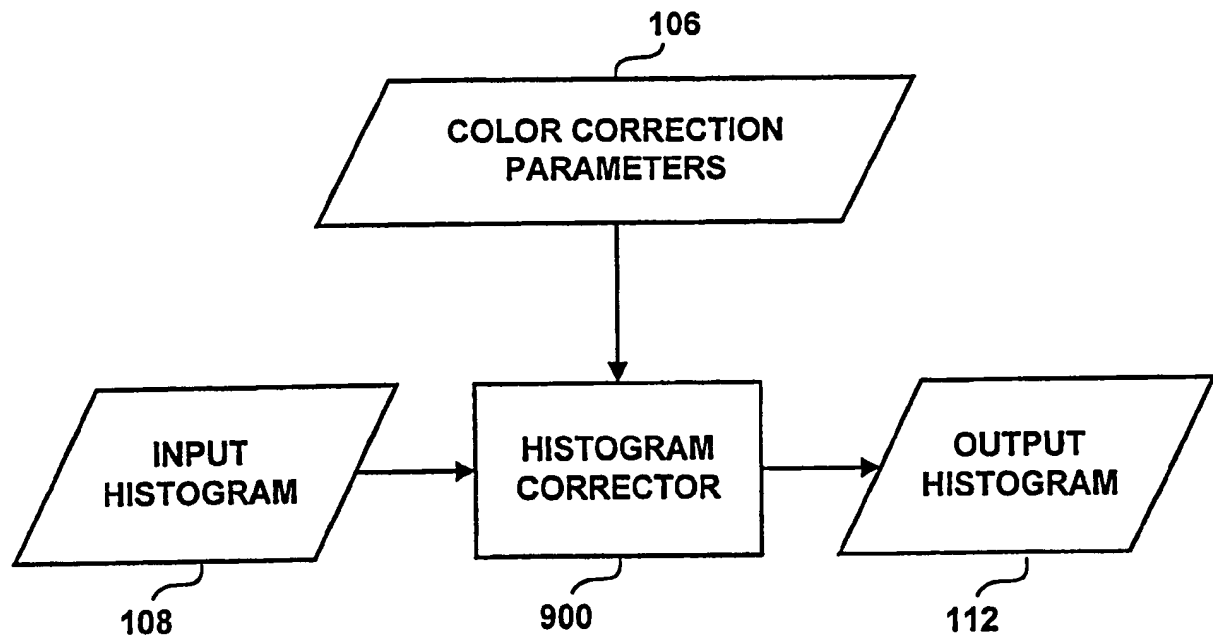


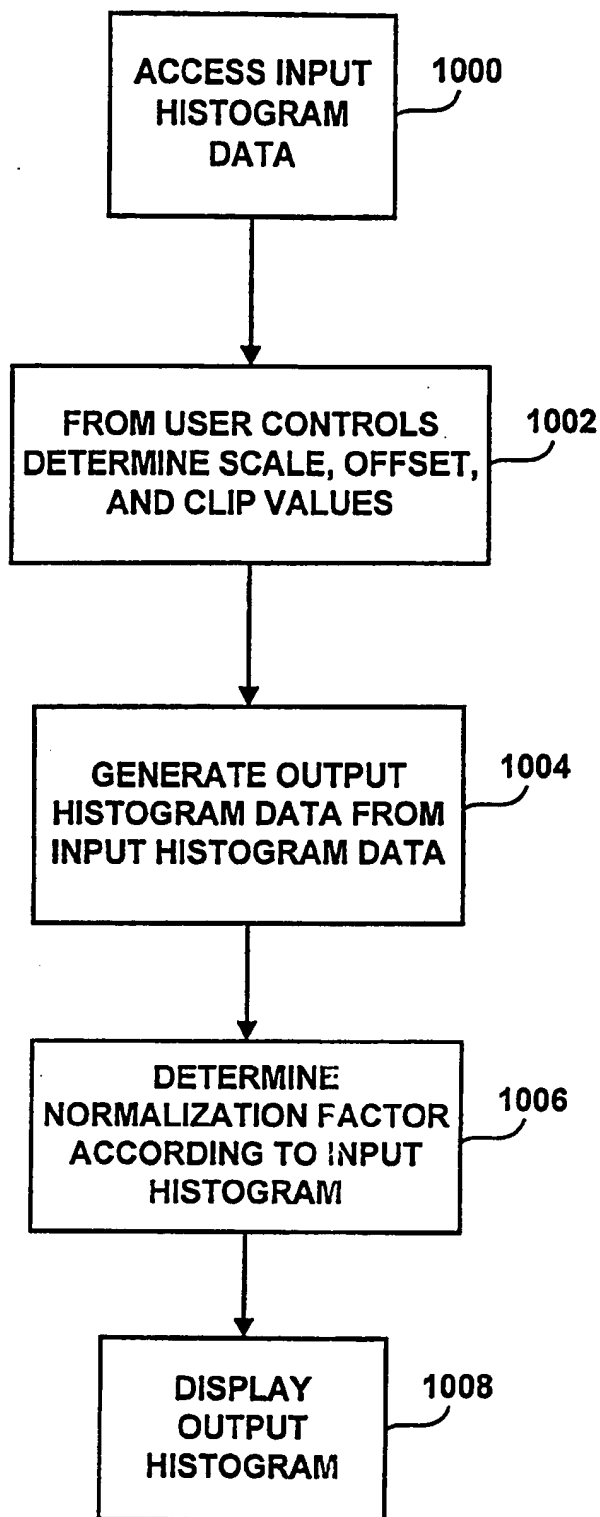
FIG. 5

**FIG. 6**

**FIG. 7**

**FIG. 8**

**FIG. 9**

**FIG. 10**

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7. •H04N1/60

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 941 037 A (SASAKI TAKASHI ET AL) 10 July 1990 (1990-07-10)	1,2
A	column 2, line 24 -column 2, line 58 claims 1,7	3-18
A	US 5 774 191 A (IVERSON VAUGHN) 30 June 1998 (1998-06-30) figure 4 claims 1-4	1-18
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-/--		

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

3 August 2000

Date of mailing of the international search report

10/08/2000

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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